VETERINARSKI ARHIV 78 (5), 417-427, 2008

The use of bat guano in the improvement of the nutritive value of poor quality roughage fed to ruminants in Tanzania

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MLAY, P. M., F. SAGAMIKO: The use of bat guano in the improvement of the nutritive value of poor quality roughage fed to ruminants in Tanzania. Vet. arhiv 78, 417-427, 2008.

ABSTRACT

An experiment was carried out on six rumen fistulated cows to determine the potential of bat guano in the treatment (GU) of poor quality roughage in comparison with the use of urea (UR) alkali from “Magadi” (MG) with untreated straws as a control (C). One kg DM of rice straws were sprayed with one litre each of either 5% Urea, or “Magadi”, or Bats’ guano suspensions. The treated straws were kept in covered plastic buckets for 14 days after this, followed by sun drying, then ground by laboratory hammer to pass through a 2.5mm screen. One gram was weighed into Dacron bags (36×36) µm pore size measuring 7.5×10.0 cm. The open ends of the bags were tightly secured on a rubber bong and incubated in the rumen of cows (in triplicates) for 0, 2, 4, 8, 12, 24, 48, 72, 96, and 120 hours. Samples were withdrawn according to the incubation schedule and immediately deep-frozen at -15^0 C. Finally the samples were manually washed until the washing water was clear and oven dried at 100^{0}C for 24 hours. The residues in the bags were weighed as the DM left and the percentage degradation for each sample calculated. The treated straws had significantly higher P (<0.05) % DM disappearance for most incubation hours compared to the control. The cost of materials required to treat 1kg DM of straws was cheapest with bats’ guano (1.25 Tsh), moderate with “Magadi” (1.50 Tsh) and highest with Urea (22.50 Tsh). It is hereby concluded that it is possible to improve the nutritive value of straws for ruminants by using bats’ guano, which is cheap, locally available and easy to apply.

Key words: bat guano, urea, “Magadi”, straws

Introduction

Poor quality roughage forms the bulk of feeds utilized in ruminants’ nutrition in the tropics. It is characterized by high fiber, high lignin, low crude protein content and low digestibility (LENG, 1990; MGHENI et al., 1994; SALEM et al., 1994; MLAY et al., 2005). This

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ISSN 0372-5480
Printed in Croatia

roughage includes standing hay and crop residues such as maize, stover, rice, sorghum, barley straws and sugarcane tops.

The major limiting factor in the utilization of such roughage is the strong lignin bonds that form a tough matrix with the digestible components (cellulose and hemi cellulose) as well as the low nitrogen content that fails to meet microbial requirement (MGHENI et al., 1994; MLAY et al., 2005). While it is well known that chemical treatment is one way of improving the nutritive value of poor quality roughage (HOMB et al., 1976; JACKSON, 1977; PRESTON and LENG, 1987), the major question is which chemicals and at what cost? Certainly industrial chemicals (sodium hydroxide, urea and ammonia) are expensive, not easy to apply and are beyond the reach of smallholder livestock keepers in a developing country like Tanzania (MELLAU et al., 2006). Thus further investigations into the potential of locally and cheaply available substances such as “Magadi” (MELLAU et al., 2006) and possibly bats’ guano are pertinent. “Magadi” is a special type of soil that is very rich in alkali locally available in many places in Tanzania and with similar characteristics to the commercial product called “Magadi” soda from Lake Magadi in Kenya (MELLAU et al., 2006).

Bat guano refers to excrement from bats (SEDGWICK, 1990). In many parts of the world, bat guano is widely used as fertilizer due to the high nitrogen content in the feces and urine and it has some nematocidal effects (KELEHER and SARA, 1996). In Tanzania there are many places full of reserves of bats’ guano such as Amboni in Tanga and Kisarawe in the Pwani regions. The Kisarawe caves, that were originally used to produce Kaolin minerals, are said to harbor three million bats producing one ton of bats’ guano per day (JUMA, 2001). Thus there is a need for further investigation on how this potential natural resource can be exploited by the local communities as a fertilizer and possibly in treatment of poor quality roughage fed to ruminants.

Materials and methods

Study area, animals and feeding regime. The research was conducted in the Department of Veterinary Physiology, Biochemistry, Pharmacology and Toxicology, Sokoine University in Tanzania using bat guano from the Kisarawe district. In sacco incubation of samples was done using six ruminally fistulated cows at Magadu Dairy farm belonging to the Department of Animal Science and Production (DASP). The animals were 7-10 years old and of average weight of 380-400 kg. They were fed *ad libitum* with hay from elephant grasses (*Pennisetum clendastenum*) as a basal diet supplemented with concentrate containing 70% maize bran (CP = 12.6), 27% sunflower cake (CP = 20%) and 3% Maclick super which contained the minerals and vitamins. The CP in concentrate mixture was 15% and supplementation rate was 2 kg/cow/day with half offered at 800 am and the other half at 4.00 pm.

Preparation of solutions and treatment procedures

Magadi" suspension. Two hundred and fifty (250) grams of "magadi" powder were weighed into 5 L gallon and 5 L of distilled water added slowly while stirring. The mixture was left to stand for 7 days; after which the fluid containing dissolved components and particles in suspension was decanted carefully to a clean container and its pH taken. The "Magadi" powder used in this study was the same batch used by MELLAU et al. (2006) and its chemical composition is indicated in Table 1 below.

Table 1. Chemical composition of "Magadi"

Component	Proportion	
	g/kg DM	mg/kg DM
Ash	832	n. d.
Magnesium (Mg)	23	n. d.
Calcium (Ca)	31	n. d.
Zinc (Zn)	n. d.	65.5
Copper (Cu)	n. d.	35.2
Phosphorus (P)	3.0	n. d.
Sodium (Na)	143	n. d.
Manganese (Mn)	n. d.	906.2
Water soluble HCO_3	176	n. d.

From Mellau et al. (2006)

Urea solution. Fifty (50) g urea were weighed and put into 1 L beaker and distilled water was added slowly while stirring and after all the crystals had dissolved the solution was made up to 1 L level and its pH taken.

Bat guano suspension. Two hundred and fifty (250) grams bat guano powder was weighed in 5 L gallon and 5 L of distilled water added followed by thorough mixing. The mixture was left to stand for 7 days; after which the fluid containing the dissolved components and particles in suspension was decanted carefully to a clean container and the pH taken.

Rice straw treatment. Three (2×2) m nylon sheets were spread on the floor and on each an equivalent amount of 1 kg DM of straw was weighed and spread on the nylon sheets. A hand spray pump (1 L volume) was filled with 1 L of the solutions and sprayed on the rice straw bundle while turning manually from time to time to ensure uniform mixing of the chemicals and the straw. Each bundle of treated straw was placed in labeled plastic buckets that were sealed and placed at room temperature for 14 days. After 14 days, the buckets were opened and duplicate samples of about 200 g weighed into large aluminum pans (12 cm diameter) and dried to constant weight at 60 °C in a hot air oven to determine DM content. The remaining straw was sun dried for a whole day and then ground with a laboratory hammer mill to pass through a 2.5 mm sieve. The ground samples were used for in sacco incubation, and chemical analyses.

Chemical analyses. Samples for determination of CP, CF, Ash and mineral contents were submitted to the Department of Animal Science Laboratory, Sokoine University of Agriculture and analyzed following standard procedures as previously outlined by ANONYMOUS (2000).

In Sacco degradability. One gram of the sun-dried straw milled to pass through a 2.5 mm screen was weighed into nylon bags (measuring in 7.5×10 cm and pore size 36×36 μm) in triplets for each incubation time. The incubation of samples was done following standard procedures as described by MELLAU et al. (2006). Samples were withdrawn at 0 (start), 2, 4, 8, 12, 24, 48, 72, 96 and 120 hours. All the bags were inserted at the same time during morning feeding and taken out as scheduled and frozen at -15 °C to arrest further microbial activity. After the longest incubation time, all samples were thawed and manually washed using running water until the water was clear. The bags were oven dried for 24 hours at 100 °C and then cooled. After cooling, the weight of residue was taken to obtain the DM remaining in each bag.

Calculations

In sacco degradation. Degradation of DM from the bags was calculated from the disappearance of the fractions from Dacron bags after washing (zero hour) and for the respective incubation times. This was done according to the equation:

$$Df = \frac{(Wi-Wr)}{W} * 100$$

Where: Df = percentage degradation fraction after incubation.

Wi = weight DM incubated bags.

Wr = weight of the fraction in the residues.

Degradation characteristics. Rumen degradability characteristics were calculated using the exponential equation by ØRSKOV and McDONALD (1979) by the equation:

$$Y(t) = a+b\ (1-e^{-ct}),$$

Where: $Y(t)$ = degradation at time t

a = water soluble part

b = non water soluble but potentially digestible fraction

c = degradation rate constant per hour

t = incubation time in hours.

Statistical analysis. This was carried out using the General Linear Model (GML) to test the differences between the means of the various parameters for each incubation time and the means compared by the Duncan Multiple range Test according to the procedures outlined in SAS (1990) with the following model:

$$Y = I + T + C + P + \varepsilon;$$

Where: Y = dependable variable

I = intercept

T = treatments (C, GU, UR and MG)

P = period (first and second run)

C = cows (1-6)

ε = random error.

Results

Chemical composition of rice straws and bat guano. The chemical composition of the rice straws is shown in table 2 below.

Table 2. Chemical compositions of the treated and untreated straws

	Treatments			
Parameter (%)	C	GU	UR	MG
DM	94.51	94.48	91.55	94.68
CP	3.02	4.70	5.85	4.08
CF	39.14	30.07	29.71	31.42
Ash	13.20	12.27	10.85	12.85

C: Control; GU: Guano; UR: Urea; MG: “Magadi”

Straws treated with bat guano and “magadi” as well as untreated straws showed relatively higher % DM compared to urea treated straws. Urea treated straws had higher % CP than bat guano and “magadi” treated straws. Untreated straws had the least % CP compared to the other treatments. “Magadi” treated straws had the relatively highest ash content.

The chemical composition of bats’ guano collected from Kisarawe caves in Tanzania is shown in Table 3. The product was rich in nitrogen (4.7%) and minerals, especially phosphorus.

Table 3. Chemical composition of bat guano

Component	Amount
% Total Nitrogen (N)	4.71
% Dry Matter (DM)	90.87
% Crude Fiber (CF)	30.06
% Ash Content	6.99
Zinc (Zn) (ppm)	95.6
Copper (Cu) (ppm)	33.44
Magnesium (Mg) (ppm)	852.4
Calcium (Ca) (ppm)	892.6
Phosphorus (P) (ppm)	4662.5
Sodium (Na) (ppm)	759.2

The pH of the treatment solutions. The pH of the solutions used in the treatment of straws is shown in Table 4. The “Magadi” suspension had the highest pH, followed by the urea solution and then the Bat guano suspension.

Table 4. The pH values of various solutions/suspensions used in treatment of rice straws

Suspension/solution	pH
Bat guano suspension	6.8
‘Magadi’ suspension	9.4
Urea solution	8.1

In sacco DM degradation. The least square Means (LSD) for %DM degradation of samples incubated in the rumen and withdrawn at 0, 2, 4, 8, 12, 24, 48, 72, 96 and 120 hours is shown in Table 5 below.

Table 5. The least square means of % dry matter (DM) degradation of straws from Dacron bags under various treatments

Time (hr)	C	GU	UR	MG	SEM	P-value
0	8.8^{a}	11.5^{ac}	16.0^{b}	15.5^{bc}	0.89	0.01
2	15.6^{a}	21.7^{b}	20.9^{bc}	20.5^{bc}	0.91	0.001
4	16.8^{a}	22.5^{b}	22.5^{b}	21.7^{b}	1.05	0.01
8	22.7^{a}	24.3^{ab}	28.7^{c}	27.3^{cb}	1.04	0.01
12	30.3^{a}	31.3^{a}	37.4^{c}	34.3^{c}	1.02	0.01
24	42.1^{a}	40.0^{b}	50.8^{c}	47.5^{c}	1.92	0.01
48	50.9^{a}	56.9^{b}	61.5^{c}	60.0^{bc}	1.42	0.01
72	59.3^{a}	59.9^{ab}	65.6^{c}	64.4^{cb}	1.31	0.01
96	62.5^{a}	62.7^{a}	68.2^{b}	67.0^{c}	1.20	0.01
120	62.5^{a}	62.7^{a}	69.9^{b}	67.1^{c}	0.90	0.01

C: Control; GU: Guano treated; UR: Urea treated; MG: "Magadi" treated; SEM: Standard error of the Means. Means with different superscript letters are significantly different ($P<0.05$).

All treatments showed significantly ($P<0.05$ to $P<0.01$) higher % degradation of DM compared to the control for most of the incubation hours.

Degradation constants. Table 6 shows the least square means of the key degradation profile of poor quality roughages as influenced by various treatments.

Table 6. The least square means of the degradation constants

Parameter/Treatment	C	GU	UR	MG	SEM	P-value
A (%)	10.10^{a}	15.43^{b}	16.05^{b}	16.56^{b}	0.643	0.0001
B (%)	52.78	49.60	53.48	51.46	0.944	0.05
C (%h^{-1})	3.66	3.54	4.26	4.04	0.0028	0.27

C: Control; GU: Guano treated; UR: Urea treated; MG: "Magadi" treated; SEM:Standard error of the mean; A: Water soluble fraction and fine particles escaping through the pores of the Dacron bags; B: Insoluble but potentially degradable fraction; C: Rate of degradation (%h^{-1}). Means bearing different superscript letters are significantly different ($P<0.05$)

Fraction A was significantly higher ($P<0.05$) for all treated straws compared to the control. There were no treatment effects with respect to the potentially degradable fraction B and the rate constant C.

Cost analysis. The costs incurred in the treatment of one kg DM of straw are shown in Table 7.

Of the three materials, urea was the most expensive, followed by "magadi" and bat guano was the cheapest.

Table 7. Estimated costs of the various materials used to treat 1 kg DM straw

Material	Price (Tshs) per kg	Amount g/kg DM straw	Cost (Tshs) per kg
Guano	25.00	50.0	1.25
Urea	450.00	50.0	22.50
'Magadi'	30.00	50.0	1.50

Discussion

In this study the high dry matter (90-95%) and low crude protein in the untreated straws showed that there is a need to devise supplementation and/or chemical treatment regime that will improve their nutritive value. Urea and bat guano treated straws had lower ash content than 'magadi' and untreated straws possibly due to the low mineral content in these substances compared to "magadi". However, with respect to individual minerals, guano had lower levels of sodium, magnesium and calcium, and slightly higher levels of zinc and almost similar levels of copper and phosphorus compared to "magadi". The low calcium level in bat guano was probably due to the fact that calcium occurs, as calcium phosphate, which is slightly soluble in water, thus tending to disappear due to leaching. Salts of most of the minerals in bat guano (nitrates, sodium and potassium compounds) are soluble and easily lost through leaching and only insoluble phosphates and sulphates are deposited and accumulate in caves (KELEHER and SARA, 1996).

In this study bat guano was found to be rich in nitrogen (4.7%) that is equivalent to about 29% CP. The observed high nitrogen content in bat guano was possibly due to hindgut fermentation by-products, chitin from insects that pass undigested along the GIT and the mixing of guano with concentrated urine from bats. This level of nitrogen was of similar order as those reported by KELEHER and SARA (1996). Surprisingly, guano crude protein levels seemed to be much higher than that reported by MLAY et al. (2003a) in sunflower cake, a valuable source of nitrogen used in ruminants feeding in Tanzania. In the ruminant animal the availability of nitrogen to rumen microbes is essential for efficient fermentation. Thus, another potential of guano is its possible use as a source of nitrogen in compounding concentrates for ruminants due to its high crude protein levels. However further studies need to be done to ascertain the levels of nitrates and nitrites in bat guano to avoid toxicity to animals.

The %DM degradation from dacron bags was higher for most incubation periods for treated straws compared to the control. Usually materials disappear from the bags through solubility, degradation or very minute particles escaping through the pores of the Dacron bags (MLAY et al. 2003a). The overall effect of chemical treatment is to break down the tough lignin bonds and to stimulate microbial activity through provision of nitrogen and minerals (LENG, 1990; MLAY et al., 2003a; MLAY et al., 2005). It can be argued that in our study, the greatest effect of the treatments was on the water soluble fraction A since the insoluble but potentially degradable fraction B and rate constant C were not significantly affected.

The observation of the improved degradation and nitrogen availability in the rumen when straws are treated with urea concurred with those made by MELLAU et al. (2006) and MLAY et al. (2003b). On the other hand "magadi" alkali's positive effects on the degradability of poor quality roughage were also reported in other works (MELLAU et al. 2006). However, the impact of bats' guano in the treatment of poor quality roughage has not yet been well documented. The increased degradability of bat guano treated straws observed in this study was possibly due to the hydrolysis of urea to ammonia, or the effects of the nitrogen and minerals to the rumen microbes in the bags or both of these factors. The effect of bat guano was much less than that of urea treatment due to the fact that the amount of urea in the guano was possibly small (the largest proportion was organic matter and minerals). Moreover, the level of urea in guano declines as it ages due to chemical reactions occurring in caves (KELEHER and SARA, 1996). Thus, better treatment effects are expected if fresh as opposed to the long-standing guano is used.

In this study, the cost of treating 1 kg DM of straw using urea, bat guano or 'magadi' was 22.50, 1.25 and 1.50 Tshs respectively. From these values bat guano was the cheapest, followed by "magadi" whilst urea treatment was the most expensive. Thus, depending on local availability, bat guano and "magadi" can be very useful in the improvement of the nutritive value of poor quality roughages in Tanzania. Where possible the two compounds can be mixed so as to capitalize the alkali effects of "magadi" and the nitrogen content in bat guano.

Acknowledgements

The authors of this article would like to express their sincere thanks to Mr. Peter Jingu, William Kibirige and Juliana Jerome of the Department of Veterinary Physiology, Biochemistry, Pharmacology and Toxicology and Mr. Muffui, G. of the Department of Animal Science and Production for their technical assistance, advice, devotion and encouragement during the whole period of this study.

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Received: 25 May 2007
Accepted: 5 September 2008

MLAY, P. M., F. SAGAMIKO: Uporaba šišmišjega gvana za povećanje hranidbene vrijednosti niskokvalitetne slame namijenjene za hranidbu preživača u Tanzaniji. Vet. arhiv 78, 417-427, 2008.

SAŽETAK

Na šest goveda s umjetnom fistulom buraga izveden je pokus radi određivanja prikladnosti šišmišjega gvana kao dodatka vlaknini slabe kvalitete u usporedbi s učinkom dodatka ureje i praška”magadi”. Kao kontrola poslužila je neobrađena rižina slama. Po jedan kg suhe tvari rižine slame bio je poprskan litrom 5%-tne ureje ili pripravkom “magadi” ili suspenzijom gvana šišmiša. Tako obrađena slama držana je u pokrivenim plastičnim posudama tijekom sljedećih četrnaest dana. Nakon toga slama je dodatno bila sušena na suncu te smrvljena do veličine od 2,5 mm. Jedan gram tako usitnjene slame bio je stavljen u Dacron vrećicu veliku 7,5×10,0 cm s porama promjera 36×36 µm. Otvori vrećica bili su čvrsto začepljeni gumenim čepom te stavljeni na inkubaciju u burag u razdoblju od 0, 2, 4, 8, 12, 24, 48, 72, 96 i 120 sati. Uzorci iz vrećica bili su uzeti u točno određene vrijeme te smrznuli pri -15 °C. Nakon toga su uzorci bili ručno ispirani sve dok voda za ispiranje nije postala bistra. Potom su bili osušeni pri temperaturi od 100 °C tijekom 24 sata. Ostatci u vrećicama bili su izvagani kao suha tvar te je izračunat postotak razgrađenosti svakoga uzorka. U obrađenim uzorcima slame ustanovljen je znatno veći (P<0,05) gubitak suhe tvari u većine uzoraka uzetih u različitim vremenskim razmacima u odnosu na kontrolu. Cijena postupka obradbe slame šišmišjim guanom bila je najmanja (1,25 Tsh). Cijena obradbe pripravkom “magadi” bila je nešto veća (1,50 Tsh). Najskupljim se pokazala obradba urejom (22,50 Tsh). Zaključeno je da se hranidbena vrijednost slame može povećati šišmišjim gvanom koji je inače jeftin, lokalno dostupan te lako primjenjiv.

Ključne riječi: šišmišji gvano, ureja, “magadi”, slama